

ENHANCING CARBON REACTIVITY IN MERCURY CONTROL IN LIGNITE-FIRED SYSTEMS

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ABSTRACT

This project was awarded under U.S. Department of Energy (DOE) National Energy Technology Laboratory Program Solicitation DE-PS26-03NT41718-01. The Energy & Environmental Research Center (EERC) is leading a consortium-based effort to resolve mercury (Hg) control issues facing the lignite industry. The EERC team, including EPRI, URS Corporation, Babcock & Wilcox, ADA-ES, Apogee, Basin Electric Power Cooperative, Otter Tail Power Company, Great River Energy, Texas Utilities, Montana–Dakota Utilities Co., Minnkota Power Cooperative, Inc., BNI Coal Ltd., Dakota Westmoreland Corporation, the North American Coal Corporation, and the North Dakota Industrial Commission, seeks to substantially enhance the capability of carbon sorbents to remove Hg from lignite combustion gases to achieve a high level of cost-effective control. The results of this effort will be applicable to virtually all utilities burning lignite in the United States and Canada and will also apply to subbituminous coals. The enhancement processes have been proven at the pilot scale and in limited full-scale tests. Additional optimization testing is continuing on these enhancements, and this project focuses on full-scale testing at four lignite-fired units: Leland Olds Station Unit 1 near Stanton, North Dakota (ND); Stanton Station Units 1 and 10 near Stanton, North Dakota; and Antelope Valley Station Unit 1 near Beulah, North Dakota.

The lignite industry has been proactive in advancing the understanding of control mechanisms and the identification of control options for Hg in lignite combustion flue gases. Over 2 years ago, the EERC and EPRI initiated a series of discussions on Hg control with utilities and coal companies working with Fort Union (North Dakota and Saskatchewan) and Texas Basin lignites, representing most of the lignites used in North America. This project is a cooperative effort of these industry partners to address the specific needs and challenges to be met in controlling Hg from lignite-fired power plants.

This project is one of three being conducted by the consortium under the DOE mercury program to systematically test Hg control technologies available for utilities burning lignite. The overall objective of the three projects is to field-test and verify options that can be applied cost-effectively by the lignite industry to reduce Hg emissions. Under this project, the EERC and other team members will test sorbent injection technologies for plants equipped with electrostatic precipitators (ESPs) only and those equipped with spray dryer absorbers combined with fabric filters (SDAs–FFs). The other two projects will test two different oxidation technologies developed to promote Hg capture in systems equipped with an ESP followed by wet flue gas desulfurization. The EERC is the prime on the one designed to use additives to promote Hg oxidation, while the other is led by URS and involves oxidation through catalysts. Taken together, the three efforts provide a systematic approach to evaluating control technologies that will help maintain the viability of lignite-fired energy production by providing utilities with lower-cost options for meeting future Hg regulations. This work will be performed with a focus on technology commercialization through industry involvement and by emphasizing communication of results to vendors and utilities throughout the project.

During the current reporting period, data from Leland Olds Station was presented at the “Combined Power Plant Air Pollutant Control Mega Symposium” (MEGA) held August 30 – September 2, 2004 in Washington, D.C. Additional data reduction is ongoing, and construction of the draft site report has been initiated. A draft of the site-specific test plan for Antelope Valley Station testing has been completed and submitted to project partners for review. Planning activities for on-site testing have been initiated. A site visit is scheduled for the week beginning October 4, 2004, which will include powdered activated carbon system setup with the support of ADA-ES, Inc., and logistical determination of sample and injection locations. Monthlong testing at Stanton Station Unit 10 has been completed. Data reduction has been initiated and is ongoing. Results from parametric testing were presented at the MEGA symposium.

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LIST OF ABBREVIATIONS

ACI	activated carbon injection
APCD	air pollution control device
AVS1	Antelope Valley Station Unit 1
BEPC	Basin Electric Power Cooperative
BH	baghouse
B&W	Babcock & Wilcox
CMM	continuous mercury monitor
DOE	U.S. Department of Energy
EERC	Energy & Environmental Research Center
EPA	U.S. Environmental Protection Agency
ESP	electrostatic precipitator
FBC	fluidized-bed combustion
FF	fabric filter
FGD	flue gas desulfurization
GRE	Great River Energy
IAC	iodine-impregnated activated carbon
ICR	Information Collection Request (EPA's)
LAC	lignite-based activated carbon
LNB	low-NO _x burner
LOS1	Leland Olds Station Unit 1
NDIC	North Dakota Industrial Commission
NETL	National Energy Technology Laboratory
OFA	overfire air
OH	Ontario Hydro
P4	We Energies' Power Plant
PAC	powdered activated carbon
PRB	Powder River Basin
SCA	specific collection area
SD	spray dryer
SDA	spray dryer absorber
SEA	sorbent enhancement additive
SS1	Stanton Station Unit 1
SS10	Stanton Station Unit 10

ENHANCING CARBON REACTIVITY IN MERCURY CONTROL IN LIGNITE-FIRED SYSTEMS

EXECUTIVE SUMMARY

The Energy & Environmental Research Center (EERC) is conducting a consortium-based effort to resolve mercury (Hg) control issues facing the lignite industry in this U.S. Department of Energy (DOE)-funded project. The EERC team, including EPRI, URS Corporation, Babcock & Wilcox (B&W), ADA-ES, Apogee, Basin Electric Power Cooperative, Otter Tail Power Company, Great River Energy, Texas Utilities, Montana–Dakota Utilities Co., Minnkota Power Cooperative, Inc., Saskatchewan Power, BNI Coal Ltd., Dakota Westmoreland Corporation, North American Coal Corporation, and the North Dakota Industrial Commission, seeks to substantially enhance the capability of carbon sorbents to remove Hg from lignite combustion gases to achieve a high level of cost-effective control. The results of this effort will be applicable to virtually all utilities burning lignite in the United States and Canada and will also apply to subbituminous coals. The enhancement processes have been proven at the pilot scale and in limited full-scale tests. Additional optimization testing is continuing on these enhancements, and this project focuses on full-scale testing at four lignite-fired units: Leland Olds Station Unit 1 near Stanton, North Dakota; Stanton Station Units 1 and 10 near Stanton, North Dakota; and Antelope Valley Station Unit 1 near Beulah, North Dakota.

The lignite industry has been proactive in advancing the understanding of control mechanisms and the identification of control options for Hg in lignite combustion flue gases. Over 2 years ago, the EERC and EPRI initiated a series of discussions on Hg control with utilities and coal companies working with Fort Union (North Dakota and Saskatchewan) and Texas Basin lignites, representing most of the lignites used in North America. This project is a cooperative effort of these industry partners to address the specific needs and challenges to be met in controlling Hg from lignite-fired power plants.

This project is one of three being conducted by the consortium under the DOE mercury program to systematically test Hg control technologies available for utilities burning lignite. The overall objective of the three projects is to field-test and verify options that can be applied cost-effectively by the lignite industry to reduce Hg emissions. Under this project, the EERC and other team members will test sorbent injection technologies for plants equipped with electrostatic precipitators (ESPs) only and those equipped with spray dryer absorbers combined with fabric filters (SDAs–FFs). The other two projects will test two different oxidation technologies developed to promote Hg capture in systems equipped with an ESP followed by wet flue gas desulfurization. The EERC is the prime on the one designed to use additives to promote Hg oxidation, while the other is led by URS and involves oxidation through catalysts. Taken together, the three projects provide a systematic approach to evaluating control technologies that will help maintain the viability of lignite-fired energy production by providing utilities with lower-cost options for meeting future Hg regulations. This work will be performed with a focus on technology commercialization through industry involvement and by emphasizing communication of results to vendors and utilities throughout the project.

Currently, carbon injection technologies have been shown to be the most viable commercial options for systems without SO₂ scrubbers, including those emitting high levels of

elemental mercury (Hg^0). Lignites, because of their low chlorine and high calcium contents, produce high levels of Hg^0 and have also shown low Hg–sorbent reactivity. Two technologies have been identified that overcome these problems by using either 1) furnace additives or 2) treated carbons to significantly increase sorbent reactivity and resultant capture of Hg. Both technologies have been successfully demonstrated in pilot-scale and short-term field tests and will be tested over a 1-month period on both a unit configured with an ESP only and one equipped with an SDA–FF combination.

During the current reporting period, data from Leland Olds Station was presented at the “Combined Power Plant Air Pollutant Control Mega Symposium” (MEGA) held August 30 – September 2, 2004, in Washington, D.C. Additional data reduction is ongoing, and construction of the draft site report has been initiated. A draft of the site-specific test plan for Antelope Valley Station testing has been completed and submitted to project partners for review. Planning activities for on-site testing have been initiated. A site visit is scheduled for the week beginning October 4, 2004, which will include powdered activated carbon system setup with the support of ADA-ES, Inc., and logistical determination of sample and injection locations. Monthlong testing at Stanton Station Unit 10 has been completed. Data reduction has been initiated and is ongoing. Results from parametric testing were presented at the MEGA symposium.

ENHANCING CARBON REACTIVITY IN MERCURY CONTROL IN LIGNITE-FIRED SYSTEMS

1.0 INTRODUCTION

The Energy & Environmental Research Center (EERC) is conducting a consortium-based effort to resolve mercury (Hg) control issues facing the lignite industry. The EERC team, including EPRI, URS Corporation, Babcock & Wilcox (B&W), ADA-ES, Apogee, Basin Electric Power Cooperative (BEPC), Otter Tail Power Company, Great River Energy (GRE), Texas Utilities, Montana–Dakota Utilities Co., Minnkota Power Cooperative, Inc., Saskatchewan Power, BNI Coal Ltd., Dakota Westmoreland Corporation, North American Coal Corporation, and the North Dakota Industrial Commission (NDIC), seeks to substantially enhance the capability of carbon sorbents to remove Hg from lignite combustion gases to achieve a high level of cost-effective control. The results of this effort will be applicable to virtually all utilities burning lignite in the United States and Canada and will also apply to subbituminous coals. The enhancement processes have been proven at the pilot scale and in limited full-scale tests. Additional optimization testing is continuing on these enhancements, and this project focuses on full-scale testing at four lignite-fired units: Leland Olds Station Unit 1 (LOS1) near Stanton, North Dakota; Stanton Station Units 1 and 10 (SS1 and SS10) near Stanton, North Dakota; and Antelope Valley Station Unit 1 (AVS1) near Beulah, North Dakota, as listed in Table 1.

Table 1. Description of Test Sites

Plant	Utility Ownership	North Dakota Lignite Mine	Boiler Type	Boiler Size, MW ¹	Particulate Control	SO ₂ Control	NO _x Control
LOS1 ²	BEPC	Freedom	Wall fired	220 (110)	ESP/SCA ³ = 320 ft ² /1000 acfm	None	LNB OFA ⁴
SS10	GRE	Freedom	Tang. fired	60	FF ⁵	Spray dryer	LNB
AVS1	BEPC	Freedom	Tang. fired	440 (220)	FF	Spray dryer	LNB OFA
SS1	GRE	Freedom	Tang. fired	140 (70)	ESP/SCA= 470 ft ² /1000 acfm	None	LNB

¹ Total size of the boiler with the value in parentheses being the test size.

² Fires mostly North Dakota lignite; however, periodically fires a 30% blend of Powder River Basin (PRB) coal.

³ Electrostatic precipitator/specific collection area.

⁴ Low-NO_x burner overfire air.

⁵ Fabric filter.

The lignite industry has been proactive in advancing the understanding of control mechanisms and the identification of control options for Hg in lignite combustion flue gases. Over 2 years ago, the EERC and EPRI initiated a series of discussions on Hg control with utilities that burn Fort Union (North Dakota and Saskatchewan) and Texas Basin lignites, representing most of the lignites used in North America. This project is a cooperative effort of these industry partners to address the specific needs and challenges to be met in controlling Hg from lignite-fired power plants.

This project is one of three being conducted by the consortium under the U.S. Department of Energy (DOE) mercury program to systematically test Hg control technologies available for utilities burning lignite. The overall objective of the three efforts is to field-test and verify options that can be applied cost-effectively by the lignite industry to reduce Hg emissions. Under this project, the EERC and other team members will test sorbent injection technologies for plants equipped with ESPs only and those equipped with spray dryer absorbers–fabric filters (SDAs–FFs). The other two projects will test two different oxidation technologies developed to promote Hg capture in systems equipped with an ESP followed by wet flue gas desulfurization (FGD). The EERC is the prime on the one designed to use additives to promote Hg oxidation, while the other is led by URS and involves oxidation through catalysts. Taken together, the three projects provide a systematic approach to evaluating control technologies that will help maintain the viability of lignite-fired energy production by providing utilities with lower-cost options for meeting future Hg regulations. This work will be performed with a focus on technology commercialization through industry involvement and by emphasizing communication of results to vendors and utilities throughout the project.

Currently, carbon injection technologies have been shown to be the most viable commercial options for systems without SO₂ scrubbers, including those emitting high levels of elemental mercury (Hg⁰). Lignites, because of their low chlorine and high calcium contents, produce high levels of Hg⁰ and have also shown low Hg–sorbent reactivity. Two technologies have been identified that overcome these problems by using either 1) furnace additives or 2) treated carbons to significantly increase sorbent reactivity and resultant capture of Hg. Both technologies have been successfully demonstrated in pilot-scale and short-term field tests and will be tested on both a unit configured with an ESP only and one equipped with an SDA–FF combination.

2.0 BACKGROUND

Mercury is an immediate concern for the U.S. electric power industry because of the U.S. Environmental Protection Agency's (EPA's) December 2000 decision that regulation of mercury from coal-fired electric utility steam-generating units is appropriate and necessary under Section 112 of the Clean Air Act (1). EPA determined that mercury emissions from power plants pose significant hazards to public health and must be reduced. The 1997 EPA Mercury Study Report to Congress (2) and the 1998 Utility Hazardous Air Pollutant Report to Congress (3) both identified coal-fired boilers as the largest single category of atmospheric mercury emissions in the United States, accounting for about one-third of the total anthropogenic emissions. On December 15, 2003, EPA published the proposed utility mercury reductions rule in order to solicit comments on multiple approaches for mercury emission control (4). EPA is currently addressing comments on the proposed rules and is scheduled to promulgate the final rule in March 2005.

Despite the fact that mercury regulations for coal-fired utilities are imminent, significant issues remain and need to be resolved. DOE's National Energy Technology Laboratory (NETL) has acknowledged that data gaps exist for lignite and PRB coals and blends, which represent almost 50% of the coal fired in the United States. These coals produce gases high in Hg⁰, which is difficult to control. Questions still exist regarding the impact of various air pollution control devices (APCDs) and technologies for lignite-fired units. Unanswered questions remain beyond

what can be addressed by the Information Collection Request (ICR) data. The lignite-focused consortium believes there is a critical need for 1) large-scale testing of sorbent injection technologies to assess enhanced Hg–sorbent reactivity for lignites and 2) field data that can be used for evaluation of technology performance and economics, the final fate of the captured mercury, and the balance-of-plant impacts. This project has been developed based on critical input from consortium members to directly address these issues and fill in data gaps for low-rank coals.

In general, lignitic coals are unique because of a highly variable ash content, ash rich in alkali and alkaline-earth elements, high oxygen levels, high moisture levels, and low chlorine content. Lignite coals typically contain comparable levels of Hg but significantly lower levels of chlorine, compared to bituminous coals. Lignites often have chlorine concentrations well below 200 ppm in the coal, whereas bituminous coals often have chlorine levels in excess of 1000 ppm. Lignite coals are also distinguished by much higher calcium contents. These differences in composition have important effects on the form of Hg emitted from a boiler and the capabilities of different control technologies to remove Hg from flue gas. Coals containing chlorine levels greater than 200 ppm (Appalachian and Illinois Basin coals) typically produce Hg in flue gas dominated by more easily removable mercuric compounds (Hg^{2+}), most likely mercuric chloride (HgCl_2). Conversely, experimental results indicate that flue gases generated from combustion of low-chlorine (<50 ppm) coal usually contain predominantly Hg^0 , which is substantially more difficult to remove than Hg^{2+} (3). Additionally, the high calcium contents of lignite coals may reduce the oxidizing effect of the already low chlorine content by reactively scavenging chlorine species (Cl , HCl , and Cl_2) from the combustion flue gas. The level of chlorine in recently tested lignite coals from North Dakota and Saskatchewan ranged from 11 to 18 ppm in the coal on a dry basis, respectively. These chlorine levels are lower than those previously reported for lignite coals (including ICR results) due in part to recent improvements in methods and instrumentation.

Lignite-fired power plants have shown a limited ability to control Hg emissions in currently installed ESPs, SDAs, and wet FGD systems (5). As stated earlier, this low level of control can be attributed to the high proportions of Hg^0 and low levels of chlorine present in the flue gas. Speciation of Hg in flue gases for lignites analyzed as part of the EPA ICR for Hg data showed that Hg^0 concentration ranged from 56% to 96% and Hg^{2+} ranged from 4% to 44%. The higher levels of Hg^{2+} were only found in a fluidized-bed combustion (FBC) system. Typically, the form of Hg in the pulverized coal- and cyclone-fired units is dominated by Hg^0 , >85% of the total. Furthermore, the relatively high Hg content of lignites (on a Btu basis) makes Hg control even more difficult compared to bituminous coals, and the average Hg^0 emitted from lignite-fired power plants is roughly 8.5 lb/TBtu (5–7).

Activated carbon injection is a demonstrated technology for adsorption of both Hg^0 and Hg^{2+} upstream of a particulate control device such as an FF or ESP. The chemical speciation of Hg affects the capture mechanism and ultimate environmental fate (7), but powdered activated carbons (PACs) have the potential to effectively sorb Hg^0 and Hg^{2+} , depending upon the carbon characteristics and flue gas composition (8). Most PAC research has been performed in fixed-bed reactors that simulate relatively long residence time applications (gas–solid contact times of minutes or hours), as would be the case for Hg capture by an FF cake (9). However, because most of the coal-burning boilers in the United States employ ESPs for controlling particulate emissions, technologies are needed that provide short-residence-time (seconds) in-flight capture of Hg^0 . The projected annual cost for PAC adsorption of Hg in a duct injection system is

significant, yet low in comparison to other technologies. Carbon-to-Hg weight ratios of 3000–18,000 (lb carbon injected/lb Hg in flue gas) have been estimated to achieve 90% Hg removal from a coal combustion flue gas containing 10 $\mu\text{g}/\text{Nm}^3$ of Hg (10). More efficient carbon-based sorbents are required to reduce the costs.

Recent EERC testing illustrates the effectiveness of sorbents injected upstream of particulate control devices. EERC pilot-scale ESP and TOXECON (activated carbon injection [ACI] between an ESP and FF) Hg removal efficiencies for Fort Union lignite coals from Saskatchewan and North Dakota (Poplar River and Freedom coals) flue gases are compared in Figure 1 to DOE test data obtained at full-scale utility boilers, with ACI into a bituminous coal combustion flue gas upstream of a TOXECONTM (pulse-jet FF) and into bituminous and PRB subbituminous coal combustion flue gases upstream of an ESP. As shown, coal type (i.e., composition) is an important parameter that affects the Hg removal efficiency of a control device. The pilot-scale results for lignite show the need for significantly higher ACI rates to achieve the same performance as for tests with eastern bituminous coals using the same configuration. These higher sorbent requirements for lignite-fired units will translate into higher operating and capital costs if this issue is not resolved.

EPRI testing at a lignite-fired power plant equipped with an SDA–FF firing Fort Union lignite indicated poor performance of conventional ACI to control Hg. Results from 2002 testing at SS10 suggested two key conclusions: 1) the SDA removed a component from the gas, such as HCl, critical to the effective removal of Hg using ACI and 2) there was a significant effect on Hg removal resulting from sorbent accumulation on the FF between cleaning. Full-scale ACI testing conducted at We Energies' Power Plant (P4), an ESP unit burning a PRB coal, also suggested limited effectiveness of PAC at high injection concentrations because of limited HCl in the gas. It is expected that Hg removal evaluations across the ESP at SS1 will result in similar

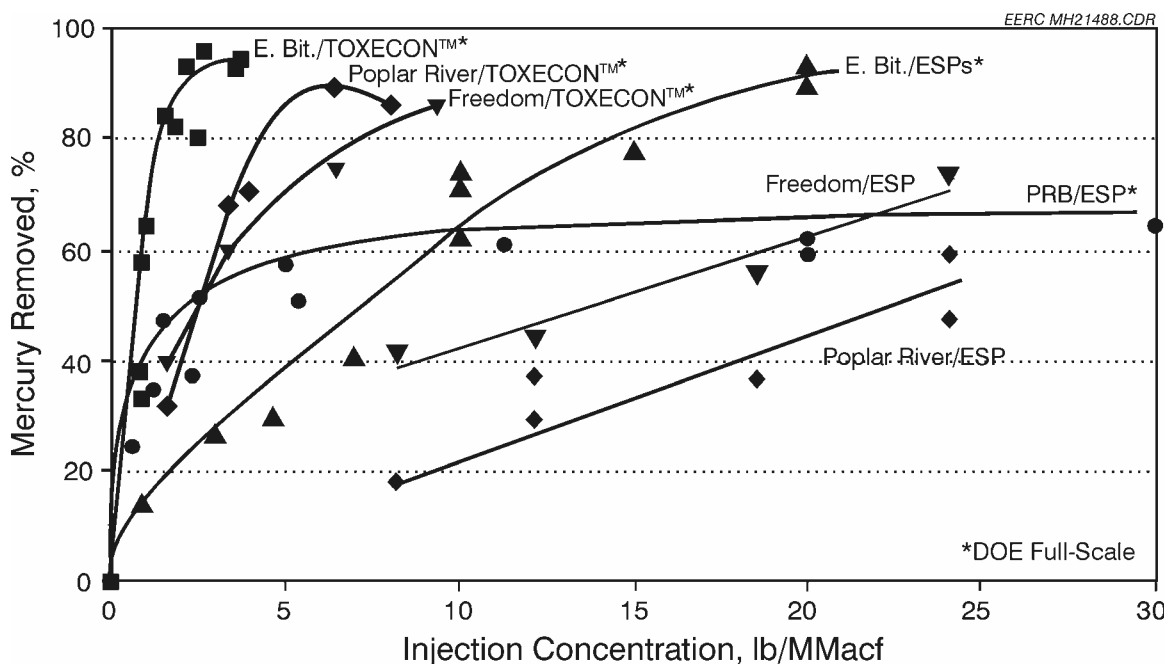


Figure 1. TOXECON and ESP Hg removal vs. ACI rate for pilot- (10) and full-scale (11) tests.

performance limitations of the untreated PAC material. Sorbents identified as candidates for testing at Stanton were chosen because of their potential to overcome the limitations associated with untreated ACI into units with SDA–FF and ESP configurations.

Researchers at the EERC and elsewhere are striving to attain a better understanding of Hg species reactions on PAC surfaces in order to produce more efficient sorbents. Functional groups containing inorganic elements such as chlorine or sulfur appear to have a significant role in bonding Hg (12). Recently, detailed analysis of sorbents derived from lignites exposed to flue gas and Hg⁰ indicated the key species impacting oxidation and retention of Hg on the surface of the carbon contain chlorine and sulfur (12). The chlorine reacts to form organically associated chlorine on the surface, and it appears that the organically associated chlorine on the carbon is the key site responsible for bonding with the Hg²⁺ species.

Sorbent enhancement additives (SEAs) have shown high potential to oxidize Hg⁰ for subsequent capture on the sorbent. SEA addition into the coal has been demonstrated at the pilot-scale level by the EERC and EPRI. Recent tests with a North Dakota lignite and very low SEA levels combined with ACI upstream of a TOXECON baghouse (BH), an *Advanced Hybrid*[™] filter, and an ESP are illustrated in Figure 2. The first part of the figure shows the baseline data for Hg emissions ranging from 9 to 12 µg/Nm³, with 80%–90% of the Hg in the elemental form. The second case is ACI with and without the use of SEA, showing a reduction in Hg emissions to 90% removal for the TOXECON configuration with SEA. The third case is the *Advanced Hybrid*[™] filter, which produced nearly 90% control efficiency with SEA. The final ESP-only case also indicated up to 90% control using SEA, albeit at relatively high injection rates. The control efficiency for the ESP-only case in Figure 2 shows significant potential improvement over past results obtained with the ESP-only illustrated in Figure 1.

This technology also has the potential to improve SDA–FF and wet FGD Hg control efficiency. Additives or oxidants added to the lignite have shown the ability to convert Hg⁰ to more reactive oxidized forms, as shown in Figure 3. Recently, short-term testing conducted at Stanton Station indicated the injection of chloride salts resulted in increased Hg²⁺ in the flue gas; up to 70% Hg²⁺ was observed. In addition, the injection of salt resulted in enhanced removal of mercury across the SDA–FF, with removal efficiencies of up to 50% without ACI. Additional testing at this lignite-fired unit also showed that the use of ACI upstream of the SDA–FF system provided significantly better performance when small amounts of SEA were added in the furnace. To summarize, the use of additives upstream of an APCD improved Hg capture both by conversion of the Hg⁰ to the more easily removed Hg²⁺ forms and by enhancing the reactivity of Hg⁰ with PACs and other sorbents.

The enhanced sorbent injection testing involves the use of sorbents that have been treated prior to injection into the flue gases. Previous EPRI testing has shown that chemically modified PAC can achieve high levels of Hg removal across SDA–FF combinations in flue gas derived from low-rank fuel. The higher costs associated with these carbons (\$6–\$7/lb) are offset by the fact that over 90% Hg removal is obtained at approximately 10% of the sorbent addition rate required for similar removals by unmodified commercial PAC. The effort will evaluate similar chemically modified carbons available at lower costs (\$1.30–\$5/lb). Successful performance by these materials will result in increased cost-effectiveness over previously tested modified and nonmodified ACI sorbents.

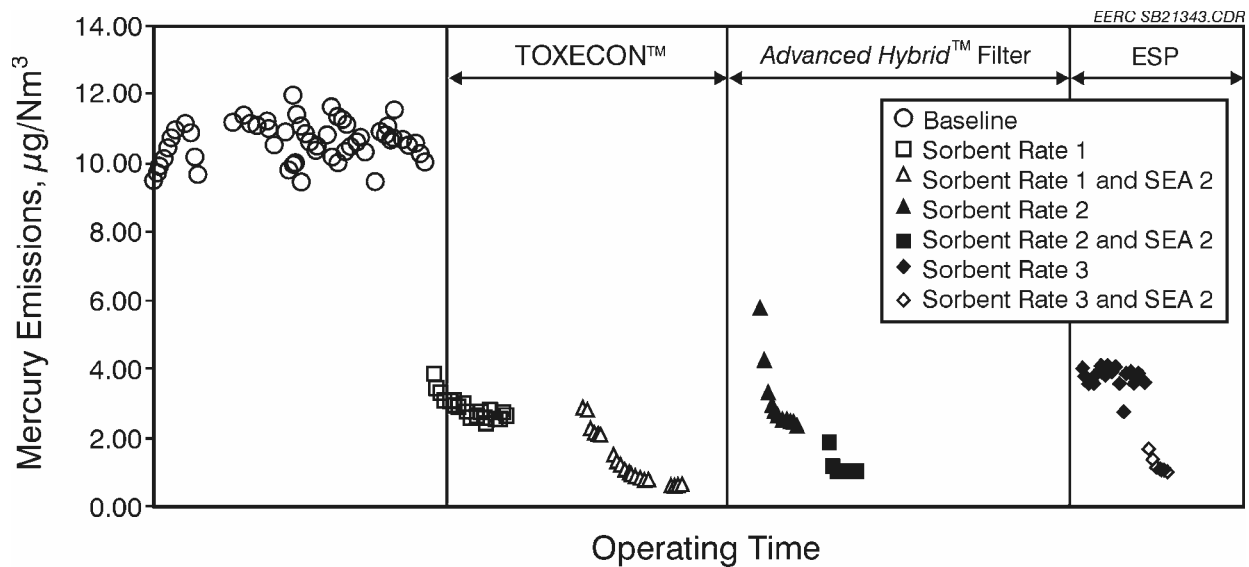


Figure 2. Hg emissions for ACI combined with coal additives.

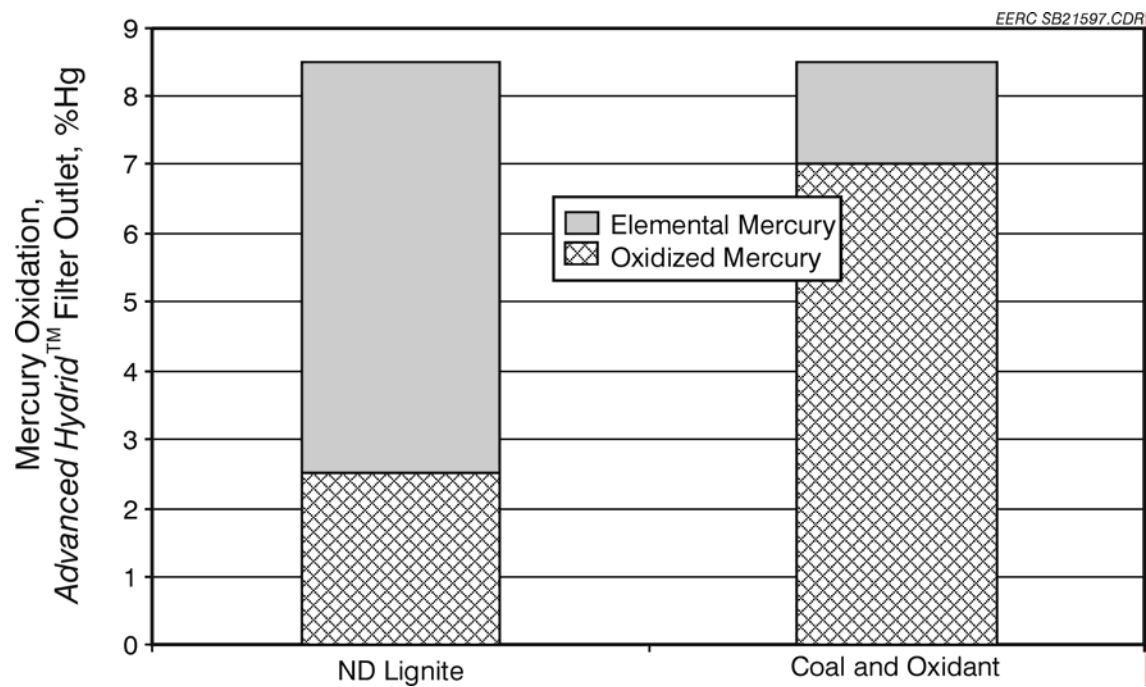


Figure 3. Oxidation of mercury through the addition of a chlorine-containing additive to coal.

EPRI conducted full-scale PAC injection tests at SS10 in April 2002. Results from these tests suggested that the mercury removal effectiveness of untreated PAC was limited. As shown in Figure 4, test results indicated that 70% removal could be achieved across the SDA–FF at an injection concentration of 6.1 lb/Macf. The performance of the iodine-impregnated carbon (IAC) (Type CB IAC) was significantly better. At both 0.7 and 4.0 lb/Macf IAC, $\geq 96\%$ removal was achieved across the SDA–FF. It is speculated that the spray dryer at SS10 removed a component from the gas, such as HCl, critical to the effective removal of mercury using untreated PAC, but not critical for carbon treated with halides such as iodine.

Full-scale PAC testing conducted at P4 on an ESP unit burning a PRB coal and EERC pilot-scale data with lignite coals (Figure 1) suggest that Hg removals will be low for untreated PAC across the SS1 ESP because of low HCl concentrations. As with the SDA–FF testing, treated carbons will be used to overcome this issue for the ESP system at SS1. The recent testing by EPRI will help define the effect of sorbent type and addition rate on mercury removal across the ESP and guide selection of sorbents for longer-term tests, as well as provide appropriate ranges of injection rates to evaluate. Recent EERC testing in summer 2003 further evaluated the use of SEA combined with ACI for lignites to better define the levels required for large-scale testing. This DOE test program will build on the previous testing to evaluate long-term performance of successful sorbents and additives as well as any effects on plant operations.

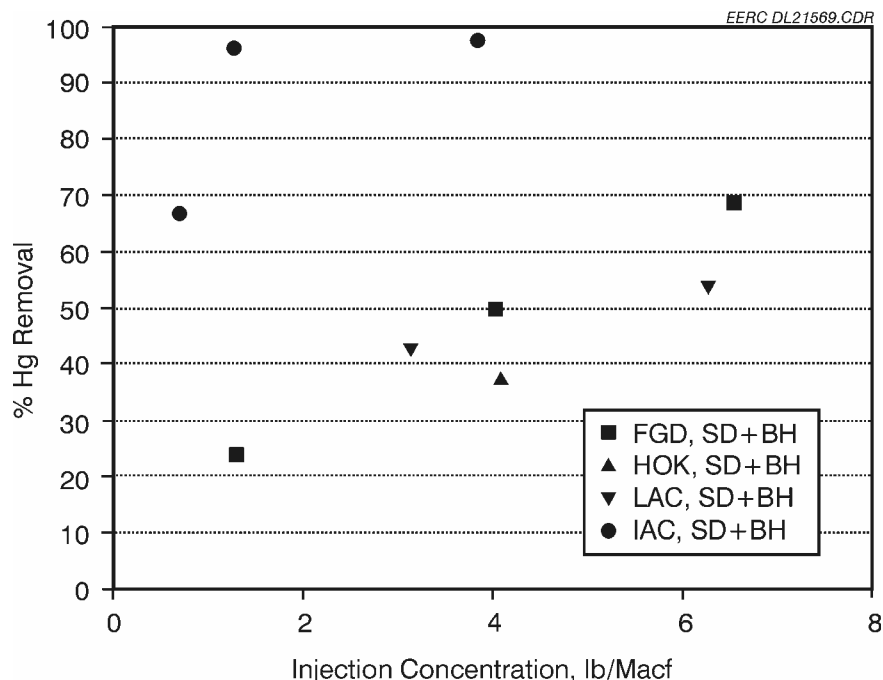


Figure 4. Mercury removal measured across the SD and BH. In the legend, the following activated carbons are called out: a Texas lignite-based carbon from NORIT Americas called DARCO[®] FGD[™], a German lignite-based carbon from Donau Carbon called DESOREX HOK, a North Dakota lignite-based activated carbon (LAC) from the Illinois State Geological Survey, and a coconut shell-based carbon available from Barnebey Sutcliffe called CB IAC.

3.0 EXPERIMENTAL

3.1 Objectives

The goal of this effort is to demonstrate two enhanced sorbent injection technologies at four lignite-fired units to obtain $\geq 55\%$ Hg removal. This effort will evaluate and demonstrate Hg control via PAC injection at two units using an ESP as the only APCD and two with SDA–FF technology. Since the speciation of Hg in flue gas from lignite is primarily Hg^0 and low reactivity with PAC is an issue, two sorbent enhancement technologies will be tested. The first technology involves SEA that will be tested to evaluate its effect on Hg speciation, PAC effectiveness, and overall Hg removal. The second involves testing of carbons treated prior to injection to greatly improve Hg reactivity and removal for a given injection rate. Supporting objectives are to 1) determine the capital and operating costs for Hg removal with PAC alone, PAC and SEA treated carbon, and SEA alone (for an SDA–FF unit) and 2) determine the balance-of-plant effects when PAC, SEA, and treated carbons are used for Hg control.

3.2 Planned Scope of Work

The two enhanced PAC technologies for Hg control will be tested at 1) LOS1, an ESP-only unit; 2) SS10, an SDA–FF unit; 3) AVS1, a larger SDA–FF unit; and 4) SS1, another ESP-only unit. Standard PAC enhanced with SEA will be tested at LOS1 and AVS1, while the treated carbons will be tested at SS10 and SS1. Flue gas Hg concentrations will be measured upstream of PAC injection and after the last APCD using continuous mercury monitors (CMMs) and American Society for Testing and Materials Method D6784-02 (Ontario Hydro [OH] method) to evaluate Hg removal rates. In addition, coal and ash samples will be collected and analyzed in order to determine the fate of Hg and its impact on by-products. Parametric tests will determine optimal process conditions for at least 55% Hg removal, and these conditions will be used to test Hg control for long-term evaluation of performance and variability. An economic analysis will be performed using the test data to assess costs for implementing a sorbent-based injection system for Hg control for each of the technologies, plants, and configurations tested.

3.3 Activities to Be Performed

3.3.1 Management

The management team includes the EERC and URS (as a major subcontractor in charge of testing at two of the four sites), with subcontracts to ADA-ES, B&W, and Apogee Scientific. The subcontractors are providing systems and technology engineering and expertise. Table 2 shows the partners directly involved for each site, as well as the lead management organization for testing activities at each site.

The project advisory team, which includes DOE, the Mercury Task Force, NDIC, and EPRI, will provide project direction and review during the course of the project.

Table 2. Site Management and Partners by Site/Task

Site	Utility Ownership	Lead Organization	Contributing Partners
Task 1 – LOS1	BEPC	EERC	URS, B&W, ADA-ES, EPRI
Task 2 – SS10	GRE	URS	EERC, EPRI, Apogee Scientific
Task 3 – AVS1	BEPC	EERC	URS, B&W, ADA-ES, EPRI
Task 4 – SS1	GRE	URS	EERC, EPRI, Apogee Scientific

3.3.2 Planning and Logistics

Project team members will jointly finalize site-specific test plans for each site/task to include a final test schedule, sampling activities, quality assurance/quality control measures specific to the site, and sampling protocols to meet project objectives. Pretest site visits were held at each site to ensure team readiness regarding equipment installation and testing locations.

3.3.3 Site Preparation

Each host site will make the necessary site preparations to accommodate the PAC/SEA systems and sampling activities, including coordinating the addition of ports, constructing safety equipment and sampling shelters, and providing power and sampling access, as required. Team members will coordinate pretest on-site activities with the host sites to ensure that all systems are operational prior to the scheduled testing.

3.3.4 Sampling Activities

The testing includes 1) baseline sampling to generate Hg removal data with the existing configuration at normal operating conditions, 2) parametric testing to generate data for a range of PAC (and where applicable SEA) or treated carbon injection rates and optimize operational parameters for Hg control, and 3) long-term testing (>1 month) to target Hg reduction of $\geq 55\%$ using optimal rates established under the parametric tests. Testing activities specific to each site are detailed in the site-specific test plans and will be added in subsequent quarterly reports.

3.3.5 Data Reduction and Analysis

The project will generate voluminous amounts of data, which will be logged carefully so that the effectiveness of SEA/PAC and treated carbons can be accurately assessed relative to both short- and long-term Hg capture/removal. This will provide DOE (and utilities) with a realistic performance value to guide decisions for future installations. Resulting data will be reduced, interpreted, and summarized to determine overall performance and costs. For each site/task, speciated Hg concentrations will be determined for various test conditions and statistically averaged over short- and long-term tests. Then, Hg removal efficiency will be calculated based on inlet coal concentrations as well as on flue gas measurements upstream and downstream of the control technology. Hg concentration and variability in the flue gas will be compared to the Hg content of the coal. Plant operation data will be logged, reduced, and plotted along with Hg concentrations to identify trends and relationships. Results will be summarized for Hg/PAC (and SEA or treated carbons as applicable) impacts on ash. Issues related to unit

operation identified during the test program will be documented, as will important design and/or process parameters that appear to limit or impact Hg control.

At the end of the testing program, using data collected during the program, economic analyses will be performed to assess full-scale implementation costs for the SEA/PAC and treated-carbon Hg removal systems for units with either an ESP or SDA–FF. Both capital and operating costs will be determined as a function of Hg removal.

4.0 RESULTS AND DISCUSSIONS

4.1 Summary of Activities

During the current reporting period, data from Leland Olds Station was presented at the “Combined Power Plant Air Pollutant Control Mega Symposium” (MEGA) held August 30 – September 2, 2004 in Washington, D.C. Additional data reduction is ongoing and construction of the draft site report has been initiated. A draft of the site-specific test plan for Antelope Valley Station testing has been completed. Planning activities for on-site testing have been initiated. Long-term testing at SS10 has been completed. Data reduction has been initiated and is ongoing. Results from parametric testing were presented at the MEGA symposium.

4.2 Leland Olds Station Testing Data

Results from OH mercury sampling are summarized in Tables 3 and 4 for the baseline and monthlong test conditions, respectively. The monthlong test was carried out with a PAC rate of 3 lb/Macf and an additive rate of 8 lb/Macf calcium chloride.

Table 3. Baseline OH Results^a

Date	Run	Location	Total Hg, μg/Nm ³	Particulate-Bound Hg, μg/Nm ³	Oxidized Hg, μg/Nm ³	Elemental Hg, μg/Nm ³
3/22/04	1	ESP in	7.79	2.21	0.46	5.11
3/22/04	1	ESP out B	6.36	<0.00002	0.64	5.72
3/23/04	2	ESP in	7.41	1.86	2.12	3.43
3/23/04	2	ESP out B	6.21	<0.00002	1.27	4.94
3/23/04	3	ESP in	6.68	2.08	0.96	3.65
3/23/04	3	ESP out B	5.96	<0.00002	1.00	4.96

^a All values dry at 3% O₂.

A summary of the CMM results for the monthlong test is shown in Figure 5. The data were used to compute an hourly average for each valid hour of sampling data. A valid hour of sampling data contains data representing at least one-half hour of sampling. The hourly average data was then averaged to obtain a daily average for each of the days with at least 12 valid hourly averages. The variability of the coal mercury can be seen in both the hourly and daily average inlet data. Control technologies tend to minimize the mercury variability at the outlet.

Table 4. Monthlong OH Results^a

Date	Run	Location ^b	Total Hg, μg/Nm ³	Particulate-Bound Hg, μg/Nm ³	Oxidized Hg, μg/Nm ³	Elemental Hg, μg/Nm ³
4/13/04	1.1	ESP in	8.76	6.16	1.25	1.36
4/13/04	1.1	ESP out	3.21	0.00006	0.46	2.74
4/14/04	1.2	ESP in	8.72	5.57	0.87	2.28
4/14/04	1.2	ESP out	3.38	0.00001	0.27	3.11
4/14/04	1.3	ESP in	9.48	7.44	0.67	1.37
4/14/04	1.3	ESP out	2.92	0.00001	0.35	2.57
4/27/04	2.1	ESP in	8.17	3.45	0.92	3.80
4/27/04	2.1	ESP out	3.15	0.0008	0.68	2.47
4/28/04	2.2	ESP in	8.50	4.96	0.42	3.11
4/28/04	2.2	ESP out	3.57	0.00002	0.83	2.75
4/28/04	2.3	ESP in	8.08	5.27	0.54	2.26
4/28/04	2.3	ESP out	3.42	0.00003	0.58	2.84
5/10/04	3.1	ESP in	6.50	1.34	0.73	4.43
5/10/04	3.1	ESP out	3.43	0.000004	0.74	2.65
5/11/04	3.2	ESP in	6.39	0.53	0.77	5.09
5/11/04	3.2	ESP out	2.88	0.0003	0.69	2.19
5/11/04	3.3	ESP in	5.86	0.59	0.36	4.91
5/11/04	3.3	ESP out	2.83	0.00001	0.59	2.24

^a All values dry at 3% O₂.^b B side of unit.

The results of the coal analysis are shown in Tables 5 and 6 for the baseline and month-long tests, respectively. The coal mercury values, along with ultimate and heating value data, were used to calculate the equivalent concentration of mercury in the flue gas from the coal. These data along with the OH mercury data from the baseline measurements are summarized in Figure 6. The figure includes an average for these values along with a standard deviation for comparison. The mercury emissions from this unit were calculated from the outlet data to be 3.82 lb/TBtu for the baseline condition. The mercury removal calculated from the baseline data was 18%. This was higher than expected based on previous data.

The coal and OH mercury data from the monthlong test are summarized in Figure 7. The variability of the data is greater because of the longer time frame over which the data was collected and the corresponding variability in the coal mercury. The average mercury removal for the monthlong test was 63%. The average mercury concentrations from Side B of this unit over the monthlong test were extrapolated to calculate a theoretical mercury emission rate of 2.04 lb/TBtu.

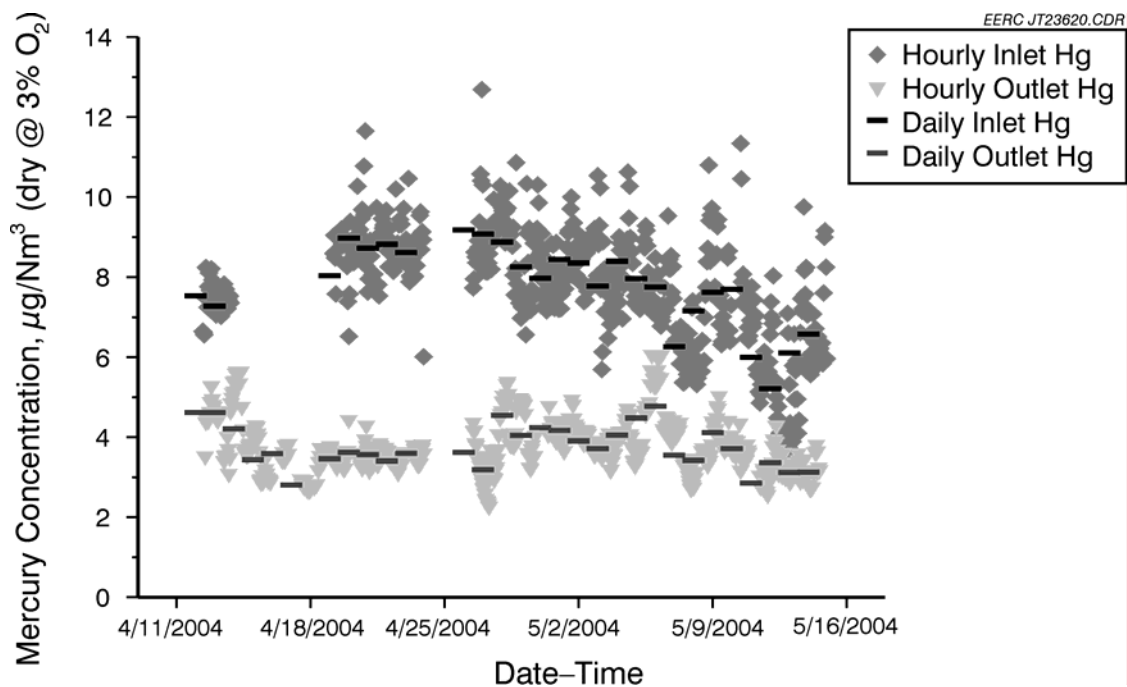


Figure 5. CMM results.

Table 5 . Baseline Coal Analysis Results^a

Parameter	Date	3/22/04	3/23/04
	Time	13:00	11:00
Hg	µg/g (dry)	0.0453	0.0490
Cl	µg/g (dry)	12	16
Proximate			
Moisture	%	37.9	38.3
Volatile Matter	%	26.5	27.2
Fixed Carbon	%	26.4	26.4
Ash	%	9.2	8.1
Ultimate			
H	%	6.7	6.8
C	%	33.5	33.2
N	%	0.7	0.7
S	%	0.51	0.5
O	%	49.3	50.6
Heating Value	Btu/lb	6186	6307
F _d	dscf/TBtu	8646	8351
Flue Gas Hg	µg/Nm ³ ^b	7.22	7.88

^a As-received unless otherwise noted.

^b Calculated dry at 3% O₂.

Table 6. Monthlong Coal Analysis Results^a

Parameter	Date	4/12/04	4/13/04	4/14/04	4/26/04	4/27/04	4/28/04	5/10/04	5/11/04	5/12/04
	Time	13:05	11:00	10:50	11:20	13:15	8:55	8:20	8:25	9:30
Hg	µg/g	0.0685	0.0538	0.0668	0.0584	0.0582	0.0589	0.0426	0.0466	0.047
Cl	µg/g	9.3	6.4	6.4	14	11	12	12	12	15
Proximate										
Moisture	%	36.4	37.7	36.7	36.1	36.2	37.5	35.4	35.8	36.2
Volatile Matter	%	27.4	28.8	27.9	27.8	28.7	28.0	28.4	28.8	28.7
Fixed Carbon	%	28.4	23.7	26.6	26.5	27.6	26.6	27.3	27.3	27.3
Ash	%	7.8	9.8	8.8	9.6	7.5	7.9	8.9	8.2	7.9
Ultimate										
H	%	6.6	6.7	6.6	6.5	6.6	6.6	6.5	6.5	6.4
C	%	34.5	33.8	34.0	34.8	36.6	35.6	37.2	36.4	35.5
N	%	0.7	0.8	0.7	0.6	0.7	0.7	0.7	0.7	0.7
S	%	0.7	0.6	0.7	0.6	0.6	0.7	0.6	0.8	0.6
O	%	49.7	48.3	49.1	47.8	48.0	48.6	46.1	47.4	48.9
Heating Value	Btu/lb	6206	6184	6193	6428	6719	6492	6530	6551	6477
F _d	dscf/TBtu	8788	8811	8725	8606	8711	8731	9164	8876	8599
Flue Gas Hg	µg/Nm ³ ^b	10.97	8.45	10.74	9.26	8.71	8.92	6.31	7.06	7.39

^a As received unless otherwise noted.^b Calculated dry at 3% O₂.

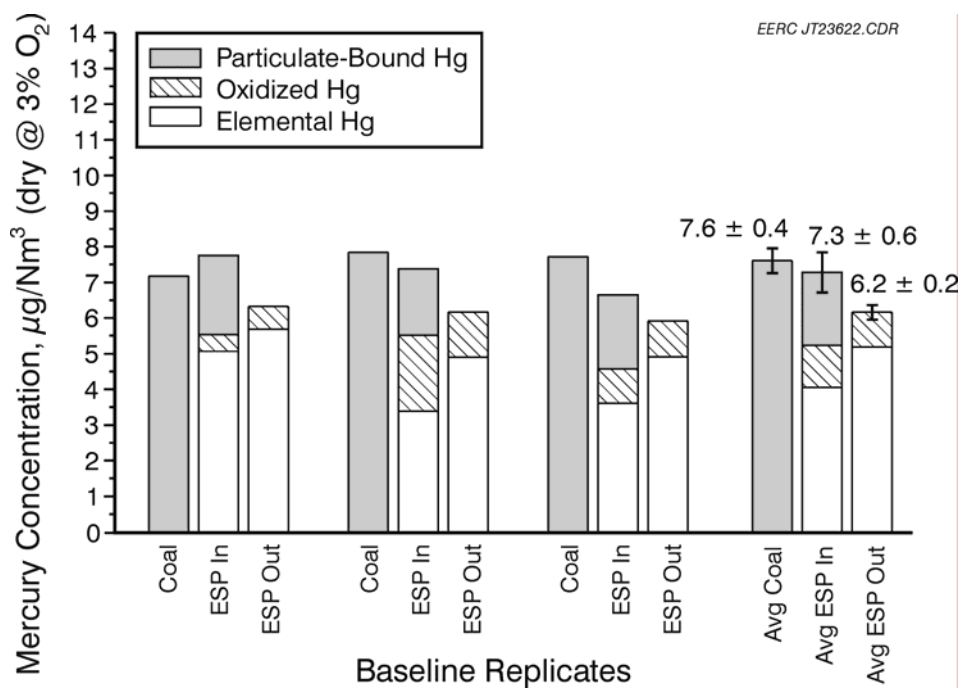


Figure 6. Baseline mercury results.

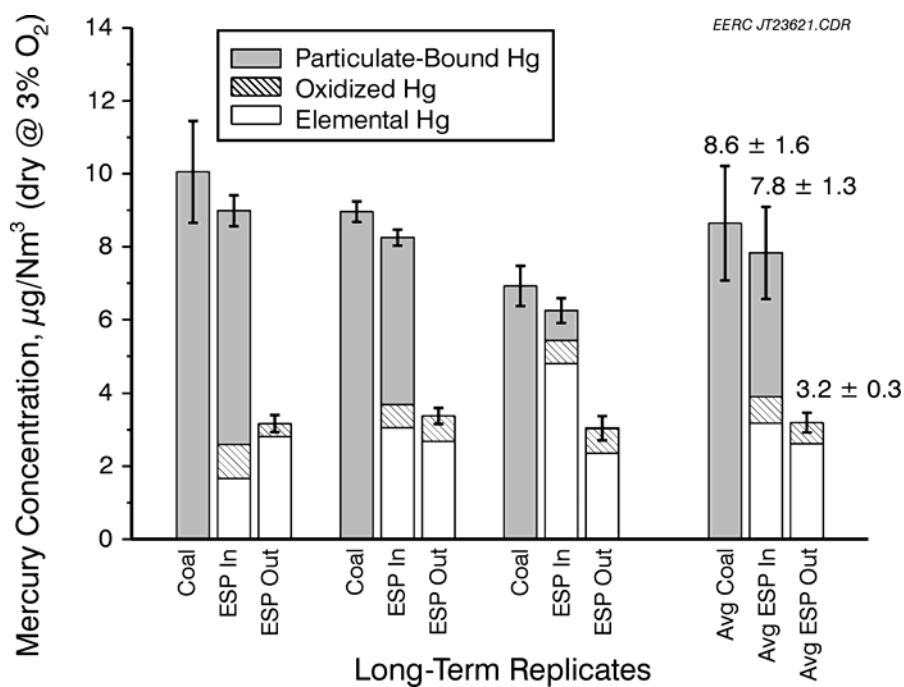


Figure 7. Long-term mercury results.

Observations of plant operation during the testing did not indicate any effects of the technologies on unit operation. Special air-cooled corrosion probes placed in the flue gas for 4 weeks during testing showed no signs of abnormal deposition or corrosion.

4.3 Stanton Station Unit 10 Parametric Testing Data (Led by URS)

A series of short-term parametric tests were conducted on SS10 to evaluate the performance of activated carbon sorbents. Based on the results of the parametric tests, a single sorbent was selected for extended full-scale tests on SS10 to observe long-term performance of the sorbent, and its effects on SD/BH system operations and combustion by-product properties.

SS10 parametric tests were completed using six sorbents: NORIT America's DARCO FGD activated carbons (FGD, E1, and E3), Barnebey Sutcliffe's iodated activated and superactivated carbons (BS IAC and BS SAC), and Sorbent Technology's brominated activated carbon (ST BAC). SS10 tests included both baseline characterization and sorbent injection tests at injection rates ranging from 0.5 to 6 lb/Mmacf.

Six sorbents were tested at SS10 as shown in Table 7. DARCO FGD carbon has been tested at Stanton and a number of other coal-fired plants and serves as a benchmark sorbent. Selection of the remaining five sorbents was based on the following criteria: 1) delivered cost; 2) mercury removal performance as verified in previous lab and/or field sorbent injection testing programs; and 3) vendor ability to supply the quantity of sorbent needed to conduct long-term testing.

Table 7. Sorbents Selected for Test Program

Sorbent Name	Unit to be Tested	Manufacturer	Average Particle Size, μm	Description	Price (\$/lb)
FGD	SS10 and SS1	NORIT Americas	19	Lignite-derived activated carbon; baseline carbon	\$0.50
BS IAC	SS10	Barnebey Sutcliff	88	CB 200xF iodated coconut shell activated carbon; "by fines" particle size; received 2004	\$7.71
FGD-E1	SS10	NORIT Americas	17	Chemically-treated, lignite-derived activated carbon	\$0.60
FGD-E3	SS10	NORIT Americas	19	Halogenated, lignite-derived activated carbon	\$0.65
BS SAC	SS10	Barnebey Sutcliff	46	Superactivated coconut shell carbon	\$0.85
ST BAC	SS10	Sorbent Technologies	20	Brominated lignite-derived activated carbon	\$0.50–1.00

Barnebey Sutcliffe's iodated carbon (CB 200xF™ and referred to in this paper as BS IAC) has been tested previously at Stanton Station and has shown up to 90% removal of mercury. It was tested again to verify performance and serve as a benchmark for the other treated carbons. While this sorbent has demonstrated high mercury removal performance, its price is \$7.71/lb, which is an order of magnitude higher than NORIT FGD.

As a lower-cost, alternative product, an untreated, superactivated version of the Barnebey Sutcliffe carbon (BS SAC) was tested. The untreated carbon BS SAC has a cost of \$0.85/lb.

Two chemically treated carbons from NORIT Americas were tested on SS10, FGD-E1 and FGD-E3. The sorbent FGD-E3 was expected to be a higher performing carbon than the FGD-E1; however, it was slightly more costly than FGD-E1 (\$0.65/lb versus \$0.60/lb).

A brominated lignite-derived activated carbon from Sorbent Technologies (ST BAC) was tested. This carbon has been demonstrated in full-scale tests at other sites to have high mercury removal efficiency at low injection rates. It was available at the same cost as the FGD-E3.

4.3.1 Mercury Speciation and Removal Data for SS10 Baseline Characterization Tests

Baseline characterization of the vapor-phase mercury concentrations in the flue gas at the SD inlet and BH outlet were conducted over a 3-day period. During this period, semi-continuous data were collected for total vapor-phase mercury and elemental mercury (oxidized mercury calculated by difference) using two CMM analyzers. In addition, simultaneous OH mercury speciation measurements were conducted at the SD inlet and BH outlet during full-load conditions to compare to the CMM analyzer results. The objectives of this series of tests were to 1) measure the native mercury concentrations at the various flue gas sample locations; 2) quantify any baseline native mercury removal; 3) measure the variability in flue gas mercury concentrations over time; and 4) compare the performance of the CMM analyzers with results from the OH standard reference method.

During the baseline evaluations both prior to and at the start of sorbent injection, the SD inlet and BH outlet total vapor-phase mercury concentrations varied from 7.5 to 13 $\mu\text{g}/\text{Nm}^3$. This range of concentrations is typical of mercury measurements made in previous programs conducted at SS10. Mercury speciation was observed at times at both locations but, generally, it was minimal during baseline measurements.

4.3.2 Parametric Sorbent Injection Tests

Table 8 provides a summary of the average total vapor-phase mercury and mercury speciation data obtained for the sorbent injection tests using the mercury CMM analyzers. Removal performance of the SD, BH and combined SD/BH controls for the various tests are provided in Table 9 and are based on mercury concentrations from Table 8. The injection rate in lb/MMacf was based on an assumed flue gas temperature of 300°F. The oxidized mercury concentration is calculated by difference using the total and elemental vapor-phase mercury measurements. A set of baseline mercury measurements with no injection was obtained at the

beginning of each sorbent injection test day to provide a benchmark for the sorbent injection tests. At the SD inlet location, the percentage of the total mercury present as oxidized mercury remained essentially unchanged between daily baseline and sorbent injection tests periods.

Mercury removals of greater than 90% were observed at an injection rate of 1.5 lb/MMacf with both NORIT FGD-E3 and Sorbent Technology STBAC. At an injection rate of 1.0 lb/MMacf, both sorbents' removal performance was greater than 85%. There was no mercury speciation measured at the BH outlet at these high removal rates except for ST BAC at 0.5 lb/MMacf. NORIT DARCO FGD was evaluated as the benchmark sorbent and achieved 75% mercury removal at an injection rate of 6.0 lb/MMacf. Removal performance across the SD and SD/BH for the six sorbents is presented in Figures 8 and 9. Review of monthlong testing data from SS10 continues. Preliminary results indicate that the performance dropped around 20% in terms of mercury removal because of system and coal changes. The monthlong test data will be analyzed and reported in subsequent quarters.

Table 8. Average SCCEM Mercury Measurements for SS10 During Baseline and Sorbent Injection

Date	Time Period	Sorbent	Injection Rate, lb/MMacf	Inlet Total $\mu\text{g}/\text{Nm}^3$	SD Outlet Total $\mu\text{g}/\text{Nm}^3$	BH Outlet, $\mu\text{g}/\text{Nm}^3$		
						Total	Hg ^o	Percent Oxidized
4/2/04	9:15–12:00	Baseline	0	11.6	10.6	12.5	12.3	0
	12:01–13:55	Darco FGD	1.5	10.5	8.6	6	6.2	0
	15:35–17:02		3.0	10.3	7.8	4.9	4.9	0
	18:15–19:05		6.0	10.4	6.8	2.6	2.6	0
4/6/04	12:00–14:28	Baseline	0	11.1	10.7	10.7	10.5	2
	15:39–16:52	BS IAC	0.5	10.4	9.9	5.4	5.4	0
4/7/04	8:40–10:00	Baseline	0	10.6	9.7	10.5	10.6	0
	10:58–12:15	BS IAC	1.0	10.4	9.3	5.7	5.6	2
	14:41–16:17		1.7	9.6	8.9	3.5	3.4	3
4/8/04	9:15–11:21	Baseline	0	8.7	8.3	9.7	9.5	2
	11:56–12:53	E-1	0.5	9.6	8.5	6.2	6.2	0
	14:42–16:01		1.5	11.4	8.4	1.9	1.9	0
	16:19–18:18		2.0	11.6	8.2	1.3	1.3	0
4/14/04	9:45–11:55	Baseline	0	8.1	8.2	9.9	9.7	2
	12:36–13:48	E-3	0.5	8.2	6.2	3.9	3.9	0
	15:23–16:41		1.0	8.2	5.7	0.9	0.9	0
	17:36–19:34		1.5	8.1	4.5	0.4	0.4	0
4/15/04	12:59–13:45	Baseline	0	9.5	9.2	10.5	10.2	3
	16:00–17:59	BS SAC	0.5	10	8.3	6.7	6.6	1
	17:09–17:59		1.5	10.4	7	4.3	4.4	0
4/16/04	8:50–11:10	Baseline	0	10.4	9.8	11.3	11.1	2
	11:59–13:13	BS SAC	1.0	9.7	7.7	6.2	6.2	0
	13:58–14:49	Baseline	0	9.8	9.4	10.2	10.2	0
	15:44–17:02	BS IAC	1.0	9.7	8.9	5.1	4.7	8
	18:01–19:45		0.5	9.2	8.8	6.9	6.6	4
4/17/04	9:53–11:30	Baseline	0	7.6	7.5	8.9	8.6	3
	12:26–13:14	ST BAC	0.5	7.5	5.5	3.6	2.8	22
	14:28–16:26		1.0	8.5	4.6	1.2	1.2	0
	16:53–19:20		1.5	9.1	3.4	0.5	0.5	0

Table 9. Summary of Measured Vapor-Phase Mercury Removals for SS10 During Sorbent Injection

Date	Time Period	Sorbent	Injection Rate (lb/MMacf)	Removal Across FGD, %	Removal Across BH, %	Overall Removal, %	
						Total	Hg ^o
4/2/04	9:15 – 12:00	Baseline	0	8	-15	-7	-
	12:01 – 13:55	Darco FGD	1.5	18	25	43	41
	15:35 – 17:02		3.0	24	31	52	52
	18:15 – 19:05		6.0	34	41	75	75
4/6/04	12:00 – 14:28	Baseline	0	3	0	3	-
	15:39 – 16:52	BS IAC	0.5	5	42	47	47
4/7/04	8:40 – 10:00	Baseline	0	8	-7	-1	-
	10:58 – 12:15	BS IAC	1.0	10	36	46	46
	14:41 – 16:17		1.7	8	55	63	65
4/8/04	9:15 – 11:21	Baseline	0	5	-14	-9	-
	11:56 – 12:53	E-1	0.5	12	24	36	35
	14:42 – 16:01		1.5	26	57	83	83
	16:19 – 18:18		2.0	29	60	89	89
4/14/04	9:45 – 11:55	Baseline	0	-1	-17	-18	-
	12:36 – 13:48	E-3	0.5	23	28	51	52
	15:23 – 16:41		1.0	30	59	89	89
	17:36 – 19:34		1.5	44	51	95	95
4/15/04	12:59 – 13:45	Baseline	0	3	-12	-9	-
	16:00 – 17:59	BS SAC	0.5	17	16	33	34
	17:09 – 17:59		1.5	33	25	58	58
4/16/04	8:50 – 11:10	Baseline	0	5	-12	-7	-
	11:59 – 13:13	BS SAC	1.0	20	16	36	36
	13:58 – 14:49	Baseline	0	5	-8	-3	-
	15:44 – 17:02	BS IAC	1.0	8	39	47	51
	18:01 – 19:45		0.5	4	21	25	28
4/17/04	9:53 – 11:30	Baseline	0	1	-15	-14	-
	12:26 – 13:14	ST BAC	0.5	26	26	52	62
	14:28 – 16:26		1.0	46	40	86	86
	16:53 – 19:20		1.5	62	32	94	94

5.0 CONCLUSIONS

LOS1 field testing has been completed. Long-term testing was carried out with a PAC rate of 3 lb/Macf, and calcium chloride was added to the coal at a rate equivalent to 8 lb/macf at an assumed gas temperature of 340°F. The demonstrations of the technologies for mercury control successfully meet the target mercury removal of 55%. Ongoing is the interpretation of data to evaluate the balance-of-plant effects, including detailed corrosion probe analysis, and economics.

Testing at AVS is tentatively scheduled to begin in February 2005. Results from testing conducted at LOS1 are being reviewed and incorporated into test plan development for AVS. A draft test plan for AVS has been submitted for review and comments.

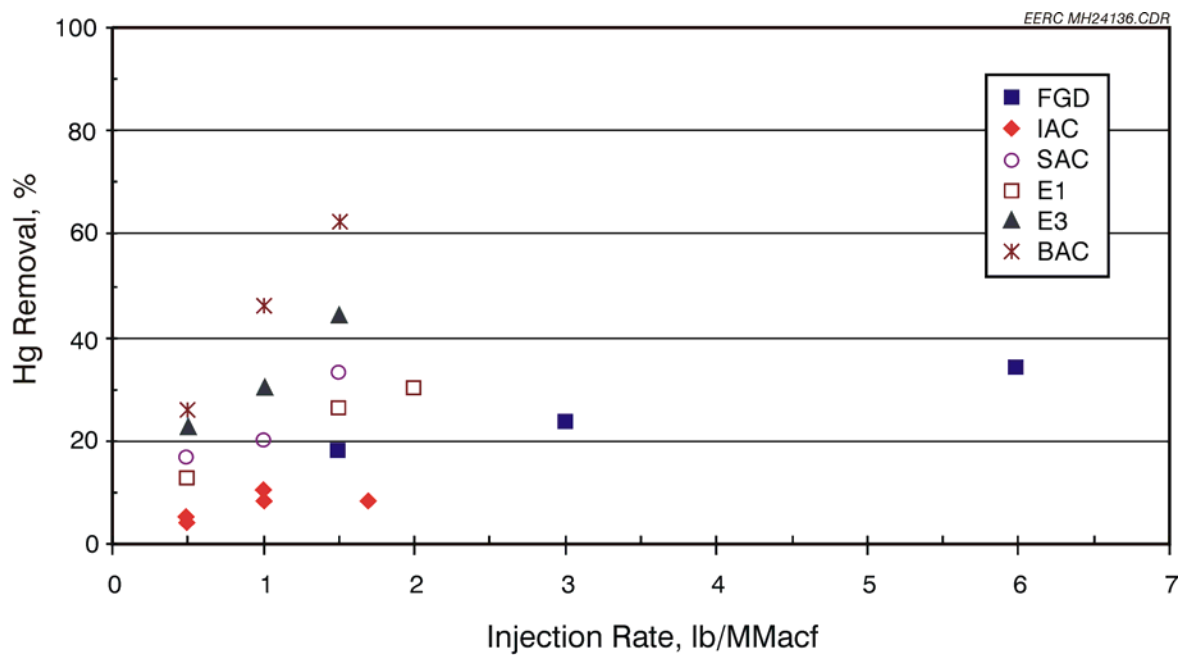


Figure 8. Mercury removal across spray dryer at SS10.

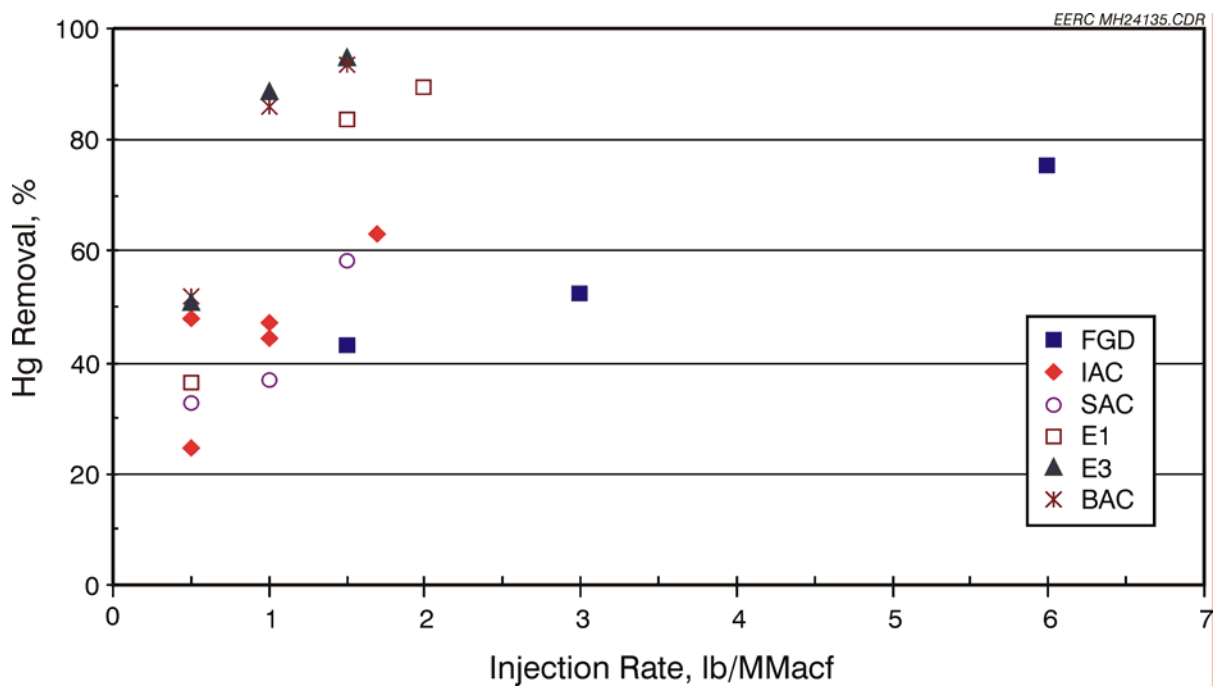


Figure 9. Mercury removal across spray dryer–baghouse combination at SS10.

SS10 parametric and monthlong testing has been completed. Preliminary data from parametric tests show good removals at treated carbon rates of 1 lb/Macf. Native removal of total vapor-phase mercury across the SS10 SD/BH was not observed during the various baseline measurement test periods. Injection of the benchmark DARCO FGD activated carbon upstream of the SS10 FGD/BH resulted in total vapor-phase mercury removals ranging from 43% to 75% at injection rates ranging from 1.5 to 6.0 lb/MMacf. Mercury removals of greater than 90% were observed at an injection rate of 1.5 lb/MMacf with both NORIT E-3 and ST BAC. At an injection rate of 1.0 lb/MMacf, both sorbent's removal performance was greater than 85%. An increase in mercury speciation at the BH outlet was not observed except for the ST BAC at the low injection rate during the parametric evaluations. Plant operation parameters did not appear to be affected by sorbent injection. Preliminary data from monthlong tests indicate a decrease in performance (about 20%) as certain system parameters change. These effects will be examined further in future quarterlies.

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